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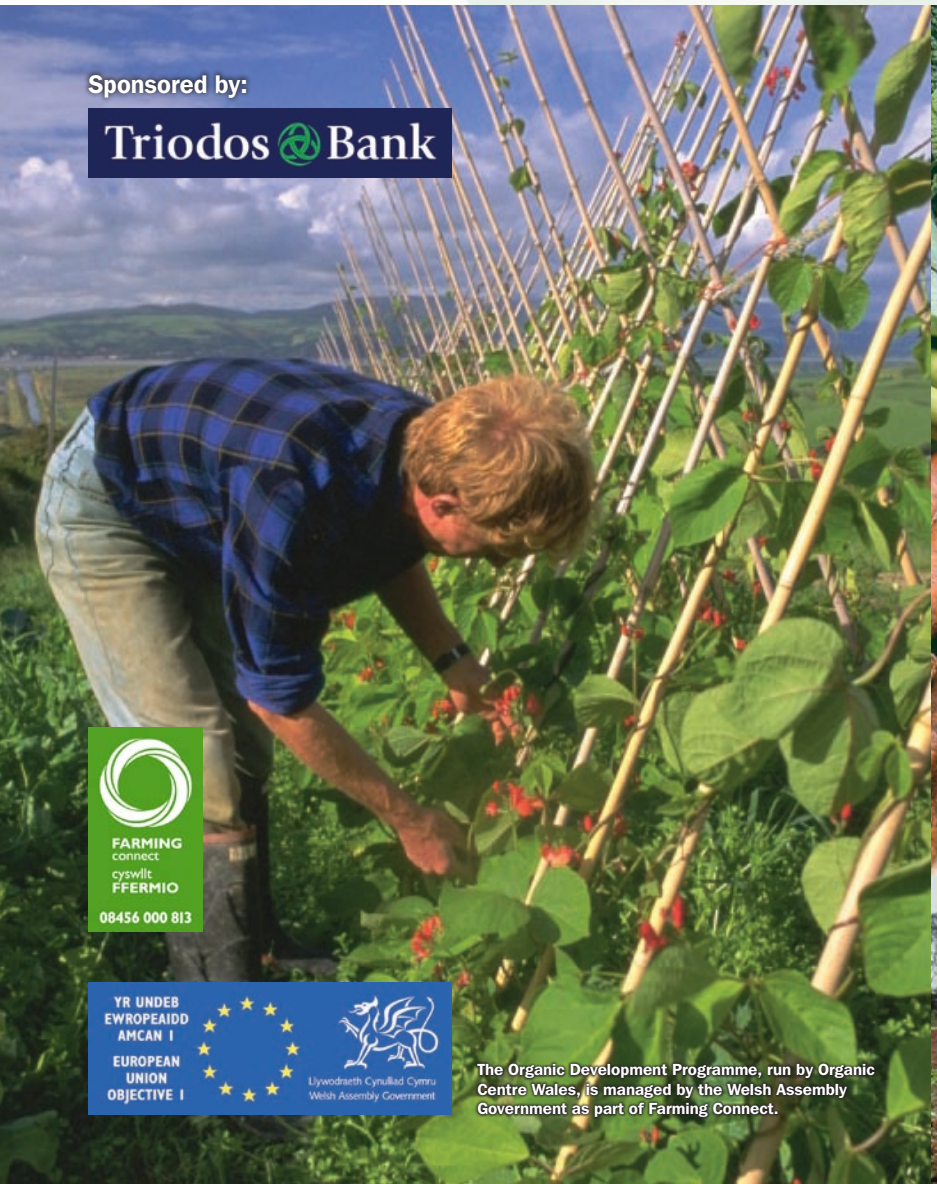
A farmer's guide to

Organic fruit and vegetable production

Tony Little, David Frost (editors)



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Foreword

Relatively few Welsh farmers have given serious thought to growing organic fruit and vegetables. However, now is a good time to consider the possibility for a number of reasons including:

- strong demand for organic horticultural products, while the supply base in Wales remains small;
- potential to significantly expand the volume and range of horticultural crops grown in Wales;
- a horticultural enterprise as an integral part of an existing livestock system may help to increase margins;
- the new Organic Farming Scheme, launched in November 2007, provides specific support for organic horticulture (£200/Ha/Year) for the first time;
- changes in CAP rules mean that as of May 2008, farmers will no longer lose the SPS entitlement on land down to horticultural crops.

This guide is aimed at farmers who are considering diversification into horticulture. It assumes a sound understanding of agricultural systems, but limited knowledge of fruit and vegetable production.

Starting a new enterprise is a significant step. As well as the opportunities, there are many challenges that need to be met such as technical and production issues; marketing outlets, logistics and distribution; access to land, machinery, labour and finance.

We hope that this guide serves as a good introduction to organic growing. We are fortunate in Wales to have a number of organisations who are able to help you put the theory into practice and these are listed at the back of this guide.

Organic Centre Wales, May 2008

1. Organic systems explained

1.1 The principles of organic farming

Organic farming is underpinned by a set of guiding principles, drawn up by the International Federation of Organic Agricultural Movements (IFOAM). These are:

- ***the principle of health:*** Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible whole;
- ***the principle of ecology:*** Organic agriculture should be based on living ecological systems and cycles, work with them and help sustain them. Food production is itself a component of the local ecology. The more in tune the production process is with that ecology, the smaller the chance of serious problems arising;
- ***the principle of fairness:*** Organic agriculture should be built upon relationships that ensure fairness with regard to the common environment and life opportunities. This principle recognizes human and social issues as well as environmental concerns;
- ***the principle of care:*** Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

1.2 Characteristics of organic farming systems

Organic farming systems aim to put these principles into practice. They rely heavily on farm generated, renewable resources and less on external inputs. They are driven by ecological and biological processes to provide nutrition, and to protect against pests and diseases.

The main elements of an organic system are:

- good soil management leading to good soil fertility, maintenance of high soil organic matter, high levels of microbial activity and good soil structure;
- well designed crop rotations for balancing fertility, controlling weeds, and minimising pest and disease problems;
- preventative and non chemical approaches to weed, pest and disease problems;
- a profitable output of organic cash crops and/or livestock.

All these aspects are discussed in detail later on in this guide.

1.3 The benefits of organic farming

Organic systems reduce the impact of the farming system on the wider environment and contribute to the conservation of wildlife and natural habitats. Specific benefits include: increased biodiversity on farms and in the landscape at large; improved physical properties of soil; lower levels of soil erosion; reduced nitrate pollution; restriction of pesticide use; reduced emissions of ammonia, carbon dioxide and methane; reduced levels of controlled waste; increased energy efficiency; improved animal welfare; and enhanced water efficiency and improvements to water quality.

1.4 Organic horticulture

Horticulture is a complex and varied sector. The main types of production systems, and their key characteristics, are as follows:

Intensive systems:

- fruit and vegetables only;
- high income - high cost systems;
- typically small market garden type holdings selling directly through local outlets such as farmers' markets, local wholesalers and box schemes;
- very labour intensive;
- usually 3 years of crops with one or two years of fertility building;
- fertility breaks are cut and mulched. Crops must be high value to compensate for the lack of income from the fertility breaks.

Field scale vegetables:

- vegetables only;
- large volumes of a relatively small range of crops;
- typical outlets are either pre-packers for supermarket sales or larger box schemes;
- high degree of mechanisation;
- economies of scale mean relatively low production costs but prices are also generally lower and quality requirements are often demanding.

Arable/ vegetable rotations:

- similar scale to field vegetables, also with a high degree of mechanisation;
- usually one vegetable crop in the rotation which acts as a break crop and helps to bring in additional income;
- can operate on heavier soils than field vegetables alone;

Mixed rotations:

- feature livestock and a range of crops (vegetable, arable and fodder);
- fertility building breaks are much longer and are grazed by stock to produce meat or milk;
- vegetable crops can be grown on poorer soils as a fertility break restores structural damage from the cultivations;
- animal manures are readily available;
- vegetables can be incorporated as one or two field-scale crops within the arable rotation. Alternatively, a wider range of vegetables can be grown within a single rotation break, a situation more akin to an intensive cropping enterprise within a relatively extensive mixed farming system;

Perennial cropping systems:

- mainly fruit production but can include some vegetables e.g. asparagus, globe artichokes and rhubarb;
- mostly woody perennials such as trees (top fruit) and bushes (soft fruit);
- crops stay in the same place year on year, so that rotations cannot be applied. This means that fertility and pest, disease and weed management have to be addressed by other methods (Strawberries are the exception, and can be rotated);

Protected cropping:

- a wide range of protected cropping systems are used;
- most comprise of a small number polytunnels, complementing a mixed vegetable operation;
- there are some are heated glasshouse systems, but these do not sit well with the organic standards and there are very few examples in Wales;
- there is often no long-term fertility building break in the rotations, as they are difficult to justify economically. Most or all of the fertility is brought in as compost and/or composted manures.

2. Soil fertility

2.1 What is soil fertility?

To some people, a fertile soil is simply one that supplies sufficient nutrients to the crop - but this is only a small part of the story. Organic producers work to a broader definition that encompasses all soil functions such as physical conditions and the level of aerobic biological activity as well as the ability to nourish plants.

2.2 How can you tell if a soil is fertile?

Awareness of the soil and its condition should be a continual process. Picking up early warning signs is vital as it can take time to address a problem that has gone undetected.

A healthy soil should **smell** like the broken down leaf litter of the forest floor – this wholesome earthy smell is typical of a healthy, well-aerated and biologically active soil. A rank marshy smell is a strong indicator of poor aeration, while little or no smell could indicate a low level of biological activity.

The sense of **touch** will tell you much about the physical state of the soil. You should also be aware of how the soil feels beneath your feet as you walk across your land - a springy softness is what you are hoping for. Hardness can indicate surface compaction or dry conditions while stickiness is evidence of poor drainage. Tracking the changes to the surface across a field by just walking up and down can highlight problem areas.

The most useful sense is **sight.** The appearance of the soil itself will, of course, provide you with important information, but the health and the type of the plants will tell you a great deal about the soil they are growing in. If weather and light conditions are favourable crops should be demonstrating good vigour if they are getting what they need from the soil. Colour is an important indicator – an even green colour from top to bottom of a crop plant and across the bed is a sign that all is reasonably well. Any variation in colour on a single plant or across the bed should be investigated – this might be a variation in the 'greenness' or there might be stress colours such as yellow or red creeping in. Weeds can provide clues to fertility and condition of the underlying soil. If the weeds are struggling, you should be worried! Some weeds can provide specific clues e.g. chickweed and fathen are indicators of good friability and nitrogen content, sorrel is an indicator of acidity and horsetail is linked with poor subsoil drainage.

One of the best methods for assessing soil structure is also the simplest, and will help you identify problems such as compaction, impeded drainage and restrictions to roots. You simply cut out a slice of topsoil and lift it out on a flat spade for a close examination of the layers, colours, the extent of root growth, earthworm activity, the structure and friability of the soil, and many more aspects.

2.3 Fertility and the organic standards

The maintenance of fertility and improving the biological activity of the soil is essential to growing crops successfully. In the first instance this is achieved using legumes, green manures or deep-rooting plants as part of the multi annual rotation. This development of soil and fertility can be further supported by the use of livestock manure and other organic material. It is desirable that such materials should come from within the system but this can be difficult in an enterprise that has no livestock. The last level of support involves the use of inorganic mineral amendments that are almost all slow release by their nature.

2.4 The rotation

As part of your conversion plan your certifying body will want to see an outline rotation and forward cropping plan that takes into account the organic standards as well as your market aspirations. It is important to realise that implementing a rotational approach is not just an exercise in compliance but that it will bring considerable benefits in terms of balancing fertility, controlling weeds, minimising pest and disease problems and improved soil management.

There is rarely one 'right' rotation for a given situation but good rotations have certain features in common. Always plan a fertility break based on forage legumes such as red and white clover, trefoil or vetch. Cropping legumes such as peas and beans do not produce enough surplus nitrogen. The break can take the form of a pure stand to be cut and mulched, a short term ley that can be cut and mulched or grazed or a longer term ley that is part of a mixed farming system. Avoid the cutting and export of forage such as silage or hay as this reduces fertility although replacement of nutrients by organic manure from within the system is perfectly acceptable.

Other factors to consider when designing a rotation are as follows:

- there should be a minimum of 4 years between successive crops of potatoes, brassicas and alliums (onion family);
- there should be a balance of weed suppressing and weed susceptible crops;
- a fertility building break based on the use of one or more forage legumes should be included;
- green manures should be used to ensure that the soil has a green cover at all times.

Some examples are shown in Box 1. They are not intended to be definitive rotations but are indications of the sort of approach that is needed. A single year of red clover cannot sustain such cropping regimes on its own and the role of the composted manure and/or compost is critical in all of these rotations. There is a dilemma in that organic principles suggest that the fertility break should be extended but this can seriously affect the financial performance of the whole rotation.

Box 1: Some examples of organic rotations

Rotation 1 **A 4 year potato / mixed vegetable rotation**

Year 1	Red clover – cut and mulch
Year 2	Potatoes – grazing rye winter green manure
Year 3	Brassicas
Year 4	Mixed vegetables + winter green manure as appropriate

The inclusion of maincrop potatoes and, potentially, a wide range of brassicas mean that this rotation requires relatively large amounts of land. Composted manure or compost should be applied where appropriate but at an equivalent rate of no higher than 25t/ha (10t/acre). The positions of the brassicas and mixed vegetables could be reversed providing sufficient compost is applied to what would be the last block in the sequence

Rotation 2 **A 5 year potato / mixed vegetable rotation**

Year 1	Red clover – cut and mulch
Year 2	Potatoes – grazing rye winter green manure
Year 3	Brassicas
Year 4	Onions, leeks, courgettes, squash and related crops
Year 5	Peas, beans, spinach family, roots.

Winter green manures as appropriate for both the last two years

The same comments on compost apply though it is likely that it will be needed in at least two years.

Rotation 3 **A 5 Year mixed vegetable rotation (no potatoes)**

Year 1	Red clover – cut and mulch
Year 2	Brassicas
Year 3	Peas, beans, lettuce, other salads
Year 4	Onions, leeks, courgettes, squash and related crops
Year 5	Spinach family, roots and

Winter green manures as appropriate. Compost applied in Year 4.

Typical winter green manures include grazing rye and vetch as single crops or as a mixture.

2.5 The use of manures and other bulky organic inputs

There is a range of inputs and materials that can be used for fertility management but these are intended to complement, rather than replace, the rotation. Other bulky organic materials that you can bring in include green waste compost providing it does not contain any food waste. All such imports must be justified and discussed with your certifying body. You should also be aware of the restriction that limits manure applications to a maximum of the equivalent of 170kg N/ha/year of agricultural area used. Care should be taken to avoid leaching as this represents both nutrient loss and pollution of the environment.

2.6 Composting

Composting is a process of controlled biological decomposition of biodegradable materials under managed and mainly aerobic conditions. The heat generated by this biological activity produces a compost that is sanitary and stable. To be successful, composting operations must be carefully managed from the mixing of the initial ingredients through the high temperature phase to the maturation phase when the compost is deemed ready for use. There are many operations producing high quality composts that are consistent in their physical, chemical and biological characteristics. The most common systems are based on windrows which are turned frequently using specialist machinery. The organic standards require bought in composts to meet certain quality standards (the PAS 100 standards).

Compost turner. Credit David Frost

The development of on-site systems can involve considerable investment that may be difficult to justify. In practice the system used on many organic holdings both large and small is the manure stack. The material is piled up on the yard or often in the corner of a field until a degree of breakdown has occurred – six months is often considered a suitable period of time for the stack although this is not explicitly stated in the UK or EU standards.

2.7 Inorganic inputs

Some externally sourced fertility inputs are allowed, although you may have to justify their use (usually through soil analysis) and get advance permission from your certifying body to use them. Virtually all the allowed inputs are slow acting, naturally occurring minerals and are usually applied as single inputs.

The most common mineral inputs are probably ground limestone and chalk and these are used for the correction of acidity (common in Wales) and the addition of calcium, an important plant nutrient in its own right. If magnesium levels are low and the soil is acid then dolomite or magnesian limestone can be used to correct both problems. Gypsum is used where calcium levels need to be boosted without changing the acidity of the soil.

Rock phosphate is another fairly common input in organic systems although assessment of the problem should include the biological activity in the soil. There are a number of inputs that contain potassium and the speed of activity varies considerably. Potassium sulphate (the only soluble input allowed in organic systems) has a fairly immediate effect while the use of rock potash or Adularian shale may not affect levels for a number of years. Most potash inputs require advance permission.

Other inputs include kieserite (magnesium), basic slag (phosphorus and a range of other elements) and stone meal. There is also provision within the standards for the application of trace elements often in soluble form but only where a clear need can be demonstrated. Trace element levels can be boosted by the use of liquid seaweed but it should be noted that the use of calcified seaweed is no longer allowed.

3. Pest, disease and weed control

Pest, disease and weed management in organic production systems is based on: crop rotation; selection of appropriate crop species and cultivars; the use naturally occurring predators and parasites; cultural and husbandry practices; and very small number of permitted crop protection products.

3.1 Pests

Soil pests

Resistant varieties, crop rotation and encouraging predators and parasites are the main ways to control soil pests, and management strategies for some key problems are outlined below:

- ***wireworm*** larvae (*Agriotes spp.*) attack many crops. In the UK, high wireworm populations are associated with long-term grass leys, so the first crop after the fertility building ley (often potato) is particularly susceptible. The use of resistant varieties is especially important for managing this pest;
- ***leatherjackets*** are the larvae of crane flies or 'Daddy longlegs' (*Tipula* spp). The grubs, up to 50mm long, can seriously damage crops such as lettuce by feeding on roots and stems below soil level. They are attacked by a range of predators including ground beetles, which can be encouraged by ground cover plants. Some birds also feed on leatherjackets and undertaking several shallow cultivations to expose the grubs helps them to do so. Keeping grass tightly grazed in later summer can also help to prevent the adult crane flies laying eggs;
- ***slugs.*** Avoid or remedy damp, poorly drained soils and weed infested areas in loose soils, all of which favour slugs. Thorough cultivation destroys slugs and exposes eggs and juveniles to desiccation and predation. Using resistant crop varieties and providing trap plants to divert slugs away from crops are also useful strategies. Some predatory beetles are important slug control agents and their populations can be increased by autumn cultivations and encouraging alternative prey when slug densities are low.

Pest of leaves, stems and fruits

There are a number of different approaches to managing pests of the above-ground parts of the plant. These include:

- ***physical barriers,*** such as fleeces and fine mesh which protect crops from aerial pest attack, for example carrot fly;
- ***timing of control measures and pest forecasting.*** Understanding when and where pests attack can assist control. For instance, growers can avoid generation peaks, harvest before damage occurs and apply crop covers before pest populations peak;
- ***biological control*** uses natural predators, parasites and pathogens to control pest populations. This can involve attracting natural predators present in the local environment, for example by planting flower rich hedgerows. Corn marigold, cornflower, corn camomile, phaecelia and umbelliferae such as hogweed attract a range of predators and parasitic wasps. You can also create additional habitats such as log or rock piles. Where there are insufficient predators and parasites around, you can buy them in from commercial biocontrol companies and release them into your crop (see Section 10);
- a very small number of ***permitted plant protection products*** can be used in organic systems. These include insecticidal soft soap which can be used against whitefly, mealy bug, scale insects, aphids, spider mite, thrips and leafhopper. Some 'biopestides', such as preparations of a toxin from the soil bacterium *Bacillus thuringiensis* (Bt), or viruses that attack insects, can also be used.

3.2 Diseases

Disease control in organic growing is more about prevention than treatment. Key management methods include:

- ***crop rotations***. You should aim for the longest possible period between crops of the same family. For most diseases four years is sufficient but some diseases are more persistent – allium white rot, club root, powdery scab on potatoes, for instance – so susceptible crops cannot be grown on badly infested sites;

- ***site selection.*** Crops grown on unsuitable sites are more vulnerable to disease. Assess the crop's needs, especially soil nutrient status, pH and water availability. Examine the site for drainage and soil compaction and remedy any problems (see Section 2);
- ***soil fertility.*** Build high levels of soil organic matter and promote a healthy soil food web as described in Section 2. The use of well prepared composts can increase the number and diversity of beneficial soil micro-organisms that can help to suppress diseases;
- ***good husbandry.*** Create the best conditions for crops to grow in through rotation design, tillage, mulching, appropriate timings for sowing, weeding and other cultivations, sowing depth and plant spacings;
- ***use of resistant varieties***. The NIAB Organic Vegetable Handbook and the COSI website (see Sections 4 and 12) are excellent sources of information covering a wide range of crops and diseases;
- ***polyculture.*** Growing different varieties or different species together can restrict the spread of diseases. Inter-cropping increases diversity within crops. This approach also works for insect pests;
- ***hygiene.*** Use only healthy seedlings and transplants and buy certified organic seed which has a guaranteed level of freedom from pest and disease problems. Wind borne pathogens need to be controlled by good sanitation and eliminating crop dumps, especially for potatoes;
- ***problem avoidance.*** Identifying problems at the outset may mean some crops are best avoided at certain sites, rotated over long periods, or only sown at particular times. Monitoring and good record keeping is invaluable.

Where disease outbreaks do occur, the following curative treatments can be used:

- ***biological controls.*** As with insect pests, on-farm biodiversity can enhance natural biological controls. As we discussed above, compost increases microbial activity and helps to suppress diseases;
- ***plant stimulants or conditioners.*** Seaweed extracts and compost teas produced from controlled microbial composting (CBC) systems can stimulate the plant's immune system as well as supplying vital trace elements.
- ***permitted plant protection products.*** *O*nly a very limited range of these products may be used in organic horticulture and are based on plant extracts and simple inorganic chemicals. For up to date information on permitted materials for pest and disease control, contact your certification body.

3.3 Weeds

There are many approaches to organic weed control, which collectively offer a real alternative to herbicides. The Defra-funded Initiative on Organic Weed Management (see Section 12) produced an excellent web based resource with detailed information on all aspects of this subject.

There are many aspects of organic weed management including:

- ***crop rotation.*** This is the most effective indirect method of minimising weed problems. Weed susceptible crops usually follow weed-suppressing crops. Alternating between autumn and spring germinating crops and between annual and perennial crops (including grass) also helps to prevent any single weed species becoming dominant and impossible to manage;
- ***timing.*** One well-timed weeding is usually better than several operations at the wrong time. Crops in the early stages of development (4- 6 weeks) are particularly susceptible to competition from weeds. However, premature weeding, that is before the main flush of weed germination, means you will probably have to weed again soon afterwards. Late weed development can seriously delay harvest especially if mechanised;
- ***transplanting techniques*** allow the crop to become established ahead of the weeds;
- ***cultural methods of control*** include stale seedbeds; blind harrowing; manipulating sowing dates and crop densities; mulches; and allelopathy. Seed rates tend to be higher in organic crops and high crop densities will help to suppress weeds in crops such as cabbages. Green manures such as grazing rye, vetch, phaecelia and mustard can also be grown between crops as an inter-row weed suppressant;

- ***mechanical weed control and weeding machinery.*** The main methods here are thermal weeding and inter-row cultivations. Membership of a machinery ring can provide access to the right kit, without prohibitive capital investment. The main types of weeders are as follows:

  - ***hoes*** are basic, but very important pieces of machinery which can be linked into the planting and drilling systems. Regular passes are best, so the weeds remain small and easily killed. Some have a disc set as near to the crop as accuracy allows and the hoes or scuffles work to this disc. This provides a sharp definition of the row and avoids burying small crop seedlings. Mechanical hoeing will benefit a crop and this is probably related to improved soil structure. It can also reduce water run off and erosion;

Steerage Hoe. Credit David Frost

  - ***flame weeders*** are usually used pre-emergence. Timing is critical, such that you kill most of the weeds but avoid damaging the still emerging crop seedlings. This technique is best in slow emerging crops like carrots where the major weed burden often appears before the crop. There are also directed flame weeders which can be used between the rows of the growing crop, which is protected with a shield;

  - ***rotary cultivators and brush weeders*** dislodge weeds with the forward movement of the tines or brushes. Some of these weeders can take out the in-row weeds but depend on the crop being deeper rooted and more robust than the weeds. They therefore work best in transplanted crops or where crop development is well ahead of the weeds;

  - ***finger and torsion weeders*** comb the weaker weeds out of a more robust crop, reducing the need for a hand weeding. They have various settings to increase the "aggression" of the tines, which is dependent on strength of the crop in the ground;

Brushweeder. Credit David Frost

  - ***Robotic weeders*** are 'state of the art' weeders that have a computerised camera that guides the machine. They are sensitive enough to work in weaker crops as the machine can differentiate between weed and crop plants. They are very expensive to buy and operate, and require large scale production to justify them economically.

4. Crop varieties

Organic conditions present a unique set of challenges for plants and breeders alike; the nutrients are in a less available form and the plant's root system has to work harder to meet the plants requirements; the restricted use of inputs means that organic growers are much more reliant on pest and disease resistance, early vigour to suppress weed growth and general good health of the plant to tolerate pest and disease problems.

4.1 Seeds, varieties and the organic standards

The organic standards require growers to use organic seed. However, this can be difficult for the horticultural sector because of the enormous diversity of crops and a lack of varieties available in organic seed to suit the range of growing conditions, seasons and markets. In practice, a derogation can be obtained from certification bodies to use non organic but untreated seed where appropriate organic material is not available.

4.2 The development and availability of organic seed

We are beginning to see some varieties of major crops (e.g. potatoes) that have been developed specifically for organic systems. However, it takes at least 10 years and a lot of money to develop and commercialise a new variety. At the moment, therefore, the majority of varieties used by organic growers are developed for conventional systems but perform relatively well under organic conditions. NIAB (National Institute for Agricultural Botany) and Garden Organic (Formerly HDRA) have worked together to develop a DEFRA funded an organic variety testing programme, the results of which are published annually by NIAB in the Organic Vegetable Handbook and Organic Centre Wales has done some work specific to Wales. The Centre for Organic Seed (COSI) is a web based resource that carries the results of all these programmes and other seed and variety related issues plus up to date news, details of events and other information. The site also provides direct access to the UK section of the Organic-x-seeds database, which records the availability of varieties in organic seed for most crops. Section 12 gives details of how to access these sources of information.

4.3 Choosing varieties

Choosing the right variety can be a complex process and you need to accept that it will probably take a few years, and lot of trial error, before you find the varieties that really suit you and your system. There are many issues you need to take into account including:

the market. This is often the last thing that breeders look at, but it is right at the top of a grower's priority list. Multiple retailers often specify the varieties they want based on a range of factors they consider important. You will also be required to deliver large volumes of product over a very short period of time so F1 hybrids, that tend to develop more uniformly, are more suitable. Supplying a market stall, a box scheme or a restaurant is a different ball game altogether. The characteristics you are looking for are probably very different. Typically you will be supplying small amounts of produce over long periods, which means that uniformity of development is much less of an issue;

yields. While many conventional breeding programmes focus on maximising yields, the organic grower often thinks more in terms of optimal yields. This takes account of the fact in organic systems nutrients are not very abundant and other characteristics, such as disease resistance are just as, if not more, important;

vigour. Good early vigour is very important in organic systems, particularly in relation to pest, disease and weed problems. In a situation where you cannot rely on chemical solutions, you need the crop to get away quickly to out-compete weeds and resist attack from pests and diseases;

resistance to pests and diseases. Certain varieties have high levels of resistance to specific pests and diseases. In Wales the main challenge is from foliar diseases. Resistance to potato blight, for example, has been the focus of many breeding programmes. Other examples include resistance to downy mildew in lettuce and rust in leeks;

seasonality. If you are producing crops throughout the year, such as cauliflowers, cabbage or lettuces, you will need a suite of varieties that mature in the different seasons, in the same way you can chose to cultivate winter or spring cereal varieties.

5. Machinery and equipment

An organic vegetable farm will need a stock of basic machinery and equipment. Mechanisation will greatly reduce hand work and will save money in the long run. Buying machinery and equipment can involve going to farm sales, dealers and advertisements in the farming press. Of course you don't necessarily need to own machinery to access it. Local contractors can often be used fairly cheaply, and machinery rings (see Section 13) can help you find the equipment you need in your local area.

The main types of machinery for a range of horticultural crops and systems are described below and weeding machinery is covered separately in Section 3:

- ***tractor*.** Choose a light weight machine and pay a bit more for reliability. A 35 - 65 horsepower 2 wheel drive is adequate for most needs, and a front loader is a useful addition. The left and right links need to be fitted with adjustable stabilisers when using most of the implements described below;
- ***plough*.** A two furrow plough is probably the best option, with a disc to cut the furrow and a skimmer to make sure all of the slice is properly inverted. Avoid the temptation to plough too deep which brings up inert subsoil, as well as wasting fuel. Heavy land can benefit from early ploughing so frost can help develop the crumb. Lighter land can be ploughed and cultivated straight away;
- ***cultivators***. The best tools for preserving and developing soil structure are spring tines. The tines are arranged in two or three rows and knock down the soil after ploughing ready for planting. They don't compact the soil and bring perennial weeds to the surface where they will dry out or can be picked off. The addition of a crumble roller or crumbler bar improves the finish;
- ***rotovators*** are useful for incorporating trash and old grass, using a PTO powered blade that chops up the soil. However, they need to be used with care as they can damage the soil structure and can create a soil pan at blade depth;

Spring tine harrow. Credit David Frost

- ***subsoilers*** have a deep working blade or blades that work below plough or rotovator pans to crack up the soil and improve drainage. Soil needs to be dry on top when subsoiling, and you should avoid going too deep. Adding a ball to the tine will make a mole plough;
- ***power harrow*.** Powered tines produce a fine seed bed by smashing up clods. They have a good work output but can lead to compaction and slumping;
- ***rollers*.** A Cambridge or ring roller is useful for producing a fine, firm seedbed that helps deter slugs. The soil needs to be fairly dry when you roll a field – if the roller starts to pick up soil, conditions are too wet. Flat rollers can be used but these are mainly for grass;
- ***planters*** are drawn behind a tractor usually with one or two operators doing the planting. They can be cam-based or disc based. They plough a furrow into which the plant is placed, which is then filled and rolled in;
- ***drills*.** Stanhay drills are popular, and can be used for a range of direct sown vegetable crops. They have a pre-holed belt for different seed types;
- ***ridging ploughs*** form the soil into a ridge using a double plough mouldboard, thereby increasing soil depth. They are mostly used for potatoes and other roots and can also be used to make simple raised beds. They may incorporate tubes to facilitate planting, especially for potatoes;
- ***toppers*** are tractor mounted mowing machines which will tidy up pasture, chop up green manures prior to incorporation and deal with crop trash. They can also be used on strawberries after harvest to mow off the crop residues, for mowing grassed crops like orchards and cane fruit and are important tools for organic weed management;
- ***manure spreaders***. As discussed in Section 2, manure is a very important source of nutrients in organic systems, so a muck spreader is a correspondingly important piece of kit;
- ***harvesters*** can pick up crops like carrots, onions and potatoes. Choose a versatile machine in good condition, such as the Faun harvester.

6. Harvesting and storing

Storing vegetables so that a wider range of produce is available over a longer period is an important part of increasing the supply of organic fruit and vegetables in Wales. Storage can also help growers get better prices because they can release produce onto the market when supplies are low and prices are, therefore, higher.

6.1 Growing for storage

What happens to the crop *prior* to entering storage is as important as conditions *in* the store itself; plants that have been grown in optimum conditions produce the best crops for storage. Immature crops or those that were stressed in the field, for example through lack of water or nutrients or pest and disease damage, will not store well. Nor will those that have been oversupplied with nutrients. Bruising of crops during harvest can lead to serious problems in store, particularly because the damage may not show up immediately.

6.2 Principles of good storage

A harvested crop is still very much alive; respiration is still producing carbon dioxide, water and heat, while the processes of ripening, maturation and finally senescence also continue in store. Successful storage relies, in part, on slowing these processes down as much as possible, thereby reducing the rate at which cells deteriorate. It also depends on limiting weight and water loss and preventing excessive heat production from respiration which otherwise results in reduced quality.

Many harvested crops are seed or other propagative material waiting for an opportunity to germinate. Keeping crops dry and excluding light will help to keep them in a dormant state. Light can also stimulate certain chemical reactions which affect the taste of the product and reduce its nutritional value.

Preventing attack from a wide range of pathogens is also a major part of good storage. This is a particular challenge in organic crops where pesticides and sprout suppressants are not permitted. The main microbial decay agents and processes are as follows:

- ***fungi.*** Fungi exist in a number of forms but generally are known to farmers and growers as white or greyish dust or flakes. Some fungi are dangerous and can cause decay and/or wounds which allow bacteria to enter. The majority of fungi do not develop under 0°C or above 50 °C. Humidity usually stimulates fungal development, so by keeping the store as dry as possible, for instance by good ventilation, you can slow the spread of diseases;
- ***bacteria.*** There are a number of different types of bacteria; beneficial ones help storage, but harmful ones cause decay. Bacteria do not reproduce themselves at very low (< 0 °C) or very high (> 65 °C) temperatures and dislike dry conditions;
- ***fermentation.*** Fruit and vegetables with a high sugar content can sometimes spontaneously start to ferment, a process by which bacteria or fungi convert the sugars into alcohol. This can be prevented by pasteurisation.

Table 1 identifies specific diseases of the main storage crops in Wales and describes some organic approaches to their management, while Table 2 summarises their storage requirements.

Table 1: Common post harvest diseases for some key crops

Crop	Diseases and deformations	Main preventative measures
Potatoes	Gangrene Skin spot Tuber blight Bacterial soft rot Dry rot Sprouting	• use disease resistant varieties • cure crops prior to storage • allow at least two weeks between haulm removal and harvest
Carrots	Carrot rootfly Grey mould Skin finish is lost when cool stored	• use a crop cover, e.g. non-woven fleece or netting • do not store damaged crops
Cabbage	Grey mould Alternaria brassicae White tips Bacterial rots	• use clean seed
Onions	Onion neck rot Fusarium basal plate rot Black mould Blue mould Bacterial disease	• follow sound rotation • keep low humidity in store • use non infected seed

Table 2: Storage requirements of some key crops in Wales

Crop	Storage conditions
Onions / garlic	Cold (0-4°C); Dry (Relative Humidity (RH) 70-80%); Good ventilation is essential. Onions can be stored in ambient ventilated stores from September until the end of March but for marketing during April-July, refrigerated storage is necessary.
Root crops	Cold (0-4 °C); Humid (RH 95-98%)
Potatoes	Cool (5-10 °C); Dry (RH 70-80%);
Cabbage	Cold (0-2°C) Humid (> 95 RH); Cabbages can be stored for up to eight months in cool stores
Squash / pumpkin	Warm (10-15°C) and dry. Ensure produce is well cured before storing

From Bevan et al 1997

6.4 Types of store

Field storage

Field storage is used by the majority of growers in Wales, and simply involves delaying harvest until the crop is required. While this method is very common, some soil types are more suitable than others. Clay soils, for instance are prone to waterlogging, which results in the produce rotting. Field storage is attractive because it is so simple, is low or even no cost and can improve the skin finish of some root crops. However, exposure to frost and pest and disease attack make it risky and there is always the possibility that weather conditions will not allow you to harvest when you need to. This may also delay the planting of a subsequent crop or fertility building ley, which means that this following crop is also affected, albeit indirectly.

Clamps

Clamps have been used for storing vegetables and fruit for centuries but have been replaced, to some degree, by cold stores in recent years. Root crops such as potatoes, carrots, beetroot, turnips, swedes, celeriac and parsnips, are best suited to clamps and can usually be stored through to March or even April if weather conditions are favourable.

Clamps are popular because they can be constructed at little cost and at short notice if necessary. However, the temperatures can be difficult to control, rising above 10°C in unvented clamps at one extreme and dropping below freezing at the other. There is also a risk of dehydration and it can be difficult to make them rodent proof.

Ambient storage

Ambient stores are above ground and are cooled by the circulation of cold air from outside. They are cheap to construct and operate and consist of:

- ducting for even air distribution and temperature control;
- a fan for use when ambient temperatures are low;
- controls to monitor and regulate store temperatures;
- insulation to maintain store temperature as outside temperatures rise.

They are suitable for most root vegetables and cabbages. Crops can be preserved until late March or April.

Cold storage

Cold storage is highly effective but very expensive and energy consuming. Grants, such as the Processing and Marketing Grant have been used to finance their construction by some enterprises. Before investing in a cold store it is worth considering the following issues:

- what types and varieties of crop are to be stored? Not all produce needs to be, or is suitable for, cold storage;
- what market do you supply?
- is the storage method appropriate for the scale of enterprise?

Other storage methods

Some growers store produce in pits or trenches, although the effectiveness of these have not been fully evaluated. The pit can be lined with straw, filled with the crop and then covered with soil (up to 25cm thick for cold climates) or a layer of organic material such as straw. Some growers in Powys are currently experimenting with this method.

In addition research is being undertaken on the following methods, although information on their practicality and feasibility is lacking:

- heat/ warm water treatment. This method can reduce rot in a number of vegetables. However opinions vary about its efficacy;
- biodegradable crop covers for protecting crops stored in the field, e.g. for carrots;
- alternative energy sources for cold storage;
- combining different storage methods to make best use of energy, e.g. using heat generated by cold storage for 'warm' (frost-free) storage.

6.6 Economics of storage

Improvements in production and marketing can improve the profitability of storage. Investment in storage facilities can also increase a grower's turnover if it allows a higher proportion of crops to be marketed as a result of better crop quality, or to be sold at a time of year when prices are higher. Some producers have benefited from Processing and Marketing Grants and there are examples of Welsh growers jointly setting up storage facilities to reduce costs.

7. Energy and emissions

7.1 Food, fuel and greenhouse gasses

Our food and farming system is completely dependent on cheap fossil fuels - Oil to power farm machinery and to make and distribute fertilisers, pesticides and feeds. Oil, coal and gas generate most of the electricity used to dry, cool and store products and to process food. Modern logistical and retailing operations involve moving large volumes of food large distances - all powered by fossil fuels. In addition to, and indeed because of, our reliance on fossil fuels the food system is a major emitter of greenhouse gases (GHGs).

Farming differs significantly from other industries, in two respects:

- as well as carbon dioxide (CO_2), it also emits nitrous oxide (N_2O) and methane (CH_4). These last two are emitted in smaller volumes, but they are important because, in terms of global warming potential, they are 21 and 310 times more powerful than carbon dioxide respectively;
- it has the ability to sequester as well as to emit carbon. There are a number of measures which can maximise sequestration including: conservation and zero tillage; mixed rotations, cover crops and green manures and composts to increase soil organic matter levels; agro forestry/ permaculture systems that help to increase above ground standing biomass; and soil conservation helps to avoid soil erosion and loss of soil organic matter.

The main agricultural and horticultural processes that generate emissions and the gases involved are summarised in Table 3 below.

Table 3: Agricultural and horticultural processes that generating GHGs

Activity	Process	Main emissions
Production of animal feeds	• Manufacture and transport of nitrate fertiliser; animal feed; manufacture and use of machinery	CO_2, N_2O
Animal housing and maintenance; associated machinery	• Heating; lighting; production of building materials; associated machinery	CO_2, N_2O
Digestion	• Enteric fermentation; manure management	CH_4, N_2O
Slurry and manure	• Storage; management and spreading	CO_2 CH_4, N_2O
Propagation/ plant raising	• Heating and ventilation of propagation houses/poly tunnel • Transport of bought in seeds, composts and transplants	CO_2, CO_2,
Cultivation	• Fuel for machinery • Release of gasses from soil	CO_2 CO_2, N_2O
Fertiliser use	• Fuel for manufacture, distribution and application • De nitrification in soil	CO_2 N_2O
Protected cropping	• Heating • Manufacture of protected structures (glasshouses and poly tunnels)	CO_2 CO_2
Storage	• Cooling and drying	CO_2

7.2 The impact of climate change

While we can be sure the implications of climate change will be profound and far reaching, predicting long term climatic conditions with any degree of precision is extremely difficult. However, by using sophisticated modelling systems, and comparing the outputs to the long term weather data, we can identify general trends with some confidence. These are likely to include:

- higher and more variable temperatures all year round;
- higher total annual rainfall and changing rainfall patterns - Wetter in the winter and drier in the summer;
- more frequent extreme weather events including droughts, very severe gales and violent storms;
- higher wind speeds;
- rising sea levels.

7.3 Adapting to a changing climate

If the precise nature of climate is difficult to predict, so too are the implications for farmers and growers. In general terms the changes we can expect to encounter are set out in Table 4. Adapting to climate change is probably the single biggest challenge facing the industry over the next 20 or 30 years. Some of the ways in which this could happen are highlighted in the table.

Table 4: Predicted impacts of climate change and potential adaptations

Impact	Adaptations
Increased potential for new crops due to higher temperatures and changing rainfall patterns	• Expand the range of crops grown, e.g. sweet corn, grapes, olives
Longer growing season due to increased temperatures, with earlier sowings and later harvest periods	• Changes to the choice of varieties or crops, particularly for vernalization
Crops will grow and ripen faster due to increased temperatures, drier summers and increased CO_2 levels	• Shifting cropping patterns
Increased risks of drought	• More irrigation/ on-farm water storage • Move production areas to wetter parts of the country • More drought resistant varieties
More problems of machinery use on waterlogged soils, increased risk of flooding and increased risk of soil erosion, especially on slopes, due to heavier winter rainfall	• Better drainage systems • Increased ground cover so that soils are never left bare • Minimal tillage/ cultivation • Replace some crops with permanent grass or forestry Ploughing and cultivation techniques to reduce losses
Increased risk of damage from radiation frosts	
Increased damage to protected cropping structures due to higher wind speeds, more severe gales and more frequent and more violent, storms	• Choose more sheltered spots • More robust structures
Changes in pest, disease and weed problems e.g. earlier attacks of aphids, slugs, and potato blight and new pests and diseases	• Changes in type and resistance levels of crop varieties • Changes in sowing/ harvesting dates to avoid problems • Develop/ adapt organic approaches to deal with new pest problems.
More quality problems due to wetter weather	• More disease resistant varieties • Faster ripening and shorter harvesting periods
Increased need for cool stores for potatoes and other crops	

7.4 Mitigating climate change

Mitigating the effects of climate change by reducing energy use and emissions from food and farming is one of the top priorities for the future. There are a number of measures you can take at farm level to reduce your energy and emissions. These are often simple things such as turning things down or off when you don't need them; routine maintenance to ensure that machines and appliances run more efficiently; using the right tractor for each piece of kit; making sure that tyre pressures are correct for the job you are doing and so on. If you are serious about reducing your energy use and emissions, the first step is to build up a detailed picture of the amount of energy you are using and where it is going. Only then can you can review the priority areas and develop a plan of action. A simple audit is one of the best ways to achieve this. There are a number of useful web based tools including http://www.cla.org.uk/Policy_Work/CALM_Calculator/ and www.calu.bangor.ac.uk

The main contribution of organic systems in this regard is to reduce the use of bought in inputs such as fertilisers and pesticides; and for livestock/ mixed systems the reduced use of compound feeds which consume large amounts of energy in their manufacture, distribution and use. They also increase the capacity of the soil to sequester carbon, mainly though practices that increase the amount of organic matter in the soil.

8. Financial issues

8.1 Supply and demand

As we have already mentioned, the UK market for organic fruit and vegetables is growing rapidly, far out stripping supply. Factors influencing demand include:

- welsh consumers are more likely to buy locally sourced organic food than elsewhere in the UK;
- there is increasing potential to supply local speciality crops;
- the Welsh Assembly Government is working to increase the proportion of local produce it procures for schools, hospitals and nursing homes;
- there is more flexibility among supermarket buyers than previously.

In addition, changes to the CAP rules and specific support for horticulture in the new Organic Farming Scheme mean that there is more publicly funded support for horticulture than ever before.

Yet, despite this, prices have been under pressure and there has been a lack of horticultural land coming into organic conversion. Also as identified at the very beginning of the guide, there are also many challenges that need to be overcome such as technical and production issues; marketing, logistics and distribution; access to land, machinery, labour and finance.

8.2 Profitability and gross margin calculations

The aim of this section is to show how the introduction of a horticultural enterprise into an existing livestock system can increase the overall profitability of the farm. The example in Table 5 takes a 100ha farm with 30 suckler cows, 28 finishing cattle, a 360 ewe flock and 6 ha of cereals. It explores what would happen, in financial terms, if the stock were cut back and 2 ha each of carrots swedes and savoy cabbage were introduced. The production costs and gross margin data is based on the Organic Farm Management Handbook. Please refer to this publication for further details on how the figures are arrived at.

The fixed costs have not been broken down for the purpose of this illustration because they are the same in both situations and do not influence the relative performance of the two systems. The total quoted in each case includes the following costs: labour; machinery costs; contractors; machinery depreciation; rent; property repairs; utilities; insurance; professional fees; sundry overheads; and bank interest/charges.

On the strength of this example growing organic vegetables appears to be an attractive proposition; the gross margin per hectare is up to 10 times greater than the margin from cattle and sheep, and the overall profitability is more than doubled. These budgets are illustrative, and you need to think carefully how they relate to the situation on your own farm. As with any enterprise, yields and markets vary from year to year and you also need to be realistic about what you can achieve in the early years of vegetable production. You won't become and expert grower in the first season, and you need to accept that you will probably need a few years to get to grips with a new set of challenges and master a range of new skills.

Table 5: Impact on profitability of introducing field vegetables into a livestock system

	Livestock and vegetables			Livestock only		
	Units	**Income/Cost per unit**	**Total Income (£)**	**Units**	**Income/Cost per unit**	**Total Income (£)**
Crops						
Cereals	6 Ha	£590.00	£3,540.00	6 Ha	£590.00	£3,540.00
Carrots	2 Ha	£4,577.00	£9,154.00	2 Ha		
Savoy Cabbage	2 Ha	£5,715.00	£11,430.00	2 Ha		
Swedes	2 Ha	£2,125.00	£4,250.00	2 Ha		
Total Crop Income			**£28,374.00**			**£3,540.00**
Livestock						
Breeding Ewes	340 Head	£42.95	£14,603.00	360 Head	£42.95	£15,462.00
Finishing Cattle	26 Head	£151.00	£3,926.00	28 Head	£151.00	£4,228.00
Suckler Cows	28 Head	£291.00	£8,148.00	30 Head		£8,730.00
Total Livestock Income			**£26,677.00**			**£28,420.00**
Forage Costs						
Permitted fertilisers and fertility building leys	88 Units	£30.00	£2,640.00	94 Units	£30.00	£2,820.00
Contract Silage Making	1 Unit	£1,100.00	£1,100.00	1 Unit	£1,200.00	£1,200.00
Seed	1 Unit	£800.00	£800.00	1 Unit	£800.00	£800.00
Other Costs						
Certification fee	1 Unit	£450.00	£450.00	1 Unit	£450.00	£450.00
Total variable costs			**£4,990.00**			**£5,270.00**
Sub Total (Sales - Variable costs)			**£50,061.00**			**£26,690.00**
Other Income						
Tir Mynydd and Environmental	100 Ha	£35.00	£3,500.00	100 Ha	£35.00	£3,500.00
Single Farm Payment	100 Ha	£180.00	£18,000.00	100 Ha	£180.00	£18,000.00
OFS Grass	88 a	£40.00	£3,520.00	94Ha	£40.00	£3,760.00
OFS Cereals	6 Ha	£60.00	£360.00	6 Ha	£60.00	£360.00
OFS Horticulture	6 Ha	£200.00	£1,200.00	0 Ha	£200.00	£0.00
Total Other Income			**£26,580.00**			**£25,620.00**
Total Farming Income			**£76,641.00**			**£52,310.00**
Total Fixed Costs			**£32,850.00**			**£32,850.00**
Total Farming Profit			**£43,791.00**			**£19,460.00**

9. Field vegetables

This section looks at how the broader principles discussed up to now apply to field crops. Subsequent sections cover protected and fruit crops.

9.1 Soil conditions

Soil conditions are very important when considering a field vegetable enterprise and there are a number of aspects that need be to taken into account:

- ***pH.*** As discussed in Section 2, the right pH is vital to crop growth. For most field vegetables 6.5 is ideal. Lime can be applied to address acidity, and you should consider using magnesium lime if magnesium is deficient. Lime needs several months to work. If the soil is very acid, make split applications – one before ploughing and again afterwards;
- ***soil type***. Top grade land makes life easier, but it is perfectly possible to grow field vegetables on good grade three land - in fact much ploughed land is in this group. Sandy loams are ideal in terms of fertility and water holding capacity. Sands are easy to work, but it is harder to build fertility and they need more water;
- ***soil structure***. Ideally the soil should be open and crumbly down to at least 450 mm. Have a really good look at the condition of the soil, as described in Section 2. Structure can be improved over a period of years with cultivation and the application of green and animal manures, but you can undo all your hard work with a single cultivation in wet conditions or a heavy handed harvest. There may also be hard iron pans slowing drainage or plough/ rotovator pans that can be improved with timely subsoiling.

9.2 Field growing systems

Most field crops are grown on bed systems. The bed width corresponds to the tractor wheels, so they can vary from 1.4 - 1.8m (56" - 72") depending on your set up. Tractor wheels can be altered but it is better to decide on one setting and stick to it. If you are sharing machinery within a group, it is obviously important that you all agree to grow on the same system

Raised beds or ridges can also be used, for which you will need specialist machinery (see Section 5). This can give extra depth of topsoil, improve drainage and facilitate lifting of roots like potatoes or carrots.

Field vegetable system. Credit David Frost

Usually, drilling or planting takes place relatively soon after the tilth is prepared. If land is stood, it can cap over or become hard due to rainfall and this may be a problem for crops with smaller seeds. Stale seed beds (see Section 3) can also be used to ensure a relatively weed free seed bed.

9.3 Propagation and crop establishment

Direct drilling

Some crops such as carrots, parsnips, peas and beans have to be direct sown as they are difficult to transplant. One of the biggest problems you need to address in this situation is weeds. The crops can take a long time to appear and in this phase, the weeds can easily get away. Rotations, stale seed beds, mechanical and flame weeding and all the other approaches discussed in Section 3 are particularly important in this context. Managing the first flush of weeds is very important as subsequent flushes are often a lot smaller.

Good vigour is vital, and many organic growers favour F1 hybrids where they are available because of their hybrid vigour and uniformity. However, as discussed in Section 4, other factors such as markets, disease resistance and the length of the harvest period are also important.

Seed crops are usually direct drilled to a stand with a precision drill, removing the need for thinning the crop to a final spacing. They can be drilled in a bed or on top of a ridge. Details of spacing and seed quantities can be found in production guides and most seed catalogues. Use new seed where possible and avoid over ordering as some seed doesn't keep and germination percentage and more importantly seed vigour are lost over time.

Transplants

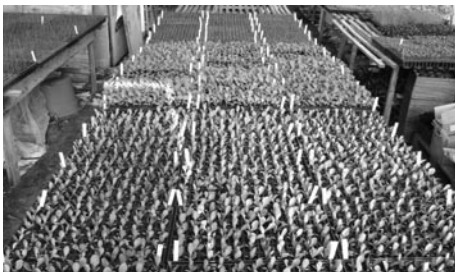
Transplanting is widely used in both conventional and organic systems. It has a number of advantages including:

- you have more control over the production environment;
- they save labour. It is easier to look after seedlings in a small protected area/ nursery bed compared to a field situation. Also, the plants are planted at their final spacing, avoiding the need for subsequent thinning;
- the stand of plants in the field is more uniform because there are no gaps due to germination failure;
- plant development is more uniform across the crop, making harvest periods and intervals more predictable;
- growing in modules makes it easy to transplant into the field by machine;
- transplanted seedlings are stronger and better able to tolerate pest and disease problems;
- transplanting into a well prepared and weed free bed gives the crop a head start, and increases its chances of out competing weeds;
- the root systems are more developed so the plant can better use of newly incorporated green manures compared to direct sowing.

The last three points are particularly relevant to organic systems.

On the other hand, this method, compared to direct sowing, is more expensive, more energy intensive and may involve a certain amount of capital outlay. This is especially true if the plants are raised under protective structures (polytunnels or glasshouses) as opposed to bareroot systems. In addition transplants may need to be watered in so the availability of irrigation facilities can also be a factor

Transplants go in on beds either by hand or by a planting machine. Stale seedbeds can be used for a weed free start. A firm bed and prompt topping and ploughing of the previous crop residues can help to manage slugs and a fleece or a micronet can keep the rabbits and pigeons at bay.



Raising vegetable transplants. Credit Cath Morris

9.4 Crop husbandry and harvesting

Once the crop is established, weeding is needed to keep the crop in front. This is usually by machine, but some hand weeding is carried out in high value weed susceptible crops such as carrots. Keep a close eye on the pest and disease situation, and manage problems as they arise as described in Section 3.

Different crops are harvested in different ways. Some, such as potatoes, are harvested in one pass, while others can be picked through every few days for weeks or even months. This latter situation is called crop standing. A crop of leeks, for instance, might be ready in October but will stand happily in the field until April and can be harvested according to demand. These crops are the stalwarts of box schemes and farmers market stalls, enabling produce to be sold right though the winter, and include red and white cabbage, carrots and parsnips, swede and turnip. You can get caught out by very severe weather but the current spell of milder winters suits this technique.

Other crops like salads will come to maturation and then go over very quickly. The trick here is to make several plantings of smaller quantities of plants over a period of time, giving you some continuity of supply. This applies to lettuce, coriander and calabrese among others.

Some crops don't stand but do store well and provided you get them out the ground at the right time, you can supply them over a relatively long period. Onions, garlic and potatoes come into this category.

Once a crop finishes, destroy the residue and spread composts and manures for the next crop. If there is a delay, sow a green manure - either a leguminous vetch or a fast-growing mustard as these will help maintain your hard won fertility.

10. Protected crops

10.1 Why grow protected crops?

Protected crops are becoming increasingly important in UK horticulture and this is reflected in the shift towards higher value / lower volume crops that has been identified in a number of recent marketing reports. Most growers in Wales have some sort of protected structure because:

- it extends the season, enabling some growers to crop virtually all year round. This helps to maintain continuity of supply and growers receive higher prices in the 'off season';
- it increases the range of crops that can be grown, particularly important if you are running a box scheme or supplying a market stall. It also means you can produce some high value/ niche crops, which are often vital to the profitability of the business;
- they are essential for plant raising in modules;
- they can be used for short-term storage or drying for field crops that need to be harvested promptly such as onions and garlic.

However, establishing a protected cropping enterprise represents a considerable investment and can be high maintenance in terms of labour and resources.

10.2 Protective structures

There are many of types of protective structure, ranging from the humble fleece up to highly sophisticated computer controlled glasshouse systems. The following is a review of the most common systems:

Fleeces on field vegetable crops

Fleeces and meshes

Fleeces are sheets of finely woven, porous material which sit on top of the crop. They have a number of functions including protection against frosts and pests (see Section 3) and to warm the soil, although they are not as effective in this last function as glasshouses and polytunnels. They can be used for field crops such as carrots and early brassicas or to harden-off seedlings before transplanting. **Meshes** also sit on top of the crop. Their main purpose is to prevent direct attack from pests such as aphids and to stop flies and butterflies/ moths from laying their eggs on the foliage (see Section 3).

Polytunnels

Polytunnels are the most common type of protected structure in Wales and are a cheap alternative to glasshouses. They can be single span (usually between and 4 to 9m wide), multi-span (several single span tunnels put together side-on) or Spanish polytunnels which are becoming increasingly popular. The latter are made of lighter material than the traditional models, and can be moved around the farm, reducing the need for rotation in the tunnel itself. You can also open the sides up to improve ventilation.

Winter salad crops with plastic mulch. Credit David Frost

You need a sheltered site and a North to South orientation will generally maximise the amount of sunlight received. You will need to be close to a water source or irrigation facilities, electricity and other utilities. You will probably require planning permission before you to put up a polytunnel, but most councils in Wales are reasonably sympathetic towards commercial growers.

Glasshouses

Glasshouses are the Rolls-Royce of protected cropping structures. They gather and retain heat much better than polytunnels, so can crop both earlier and later under glass. They are, however, much more expensive to establish and maintain (although the glass lasts much longer than plastic), and for many growers the cost is prohibitive.

10.3 Irrigation systems

Overhead or sprinkler irrigations systems are probably the simplest and cheapest option, and are particularly useful during the establishment phase of direct sown crops. However there are a number of potential problems: they can lead to high humidity, and therefore increased disease levels; they increase the risk that spores of pathogens are splashed up onto the leaves of the crop; and water marks on foliage and fruit reduce quality. They are also unsuitable if you are growing the crop under a mulch for weed control or to increase soil temperatures.

For these reasons, trickle irrigation systems such as porous ooze pipes, or drip feed systems are usually preferred. They are also much more efficient because they deliver the water direct to the roots of the plant.

10.4 Crops, rotations and fertility building strategies

There are three main cropping periods:

- **spring/ early summer crops** e.g. early carrots, beetroot, radishes, peas, lettuce and other salads;
- **summer crops** e.g. solanaceous crops (tomatoes, peppers, aubergines) and cucurbits (courgettes, melons and cucumbers);
- **autumn/ winter crops** e.g. leafy salad/ vegetable crops such as lettuces, oriental greens (mizuna, pak choi, green-in-the-snow), rocket and land cress.

Most growers are looking to get the maximum out of their polytunnels and will want to crop them practically all year round. Providing sufficient nutrients to support an intensive production system, while staying within both the letter and the spirit of the organic standards is a challenge. However, the standards do recognise that protected cropping is a special case. One of the key differences, that they do not impose an upper limit on the amount of Nitrogen supplied to the soil. They are also less prescriptive with regard to rotations and allow mono or annual cropping of the same genus except in the case of alliums, potatoes and brassicas.

In terms of fertility, protected systems rely heavily on green manures, animal manures and homemade composts. It is difficult, economically speaking, to justify long term fertility building leys so green manures tend to be fast growing species that fix large amounts of nitrogen quickly and produce lots of biomass. They are then incorporated into the soil to feed the soil microbes and the subsequent crop. Typical legumes include vetches, winter tares, crimson or sweet clover. It is also possible to undersow some crops -especially the taller growing crops like cucumbers and tomatoes - with longer term, lower growing clovers and trefoils.

Given the range of crops grown, and the less rigid application of the rotation standards, it is hard to define a typical rotation, but some examples are given in Box 2 below. They are inevitably a fine balance between the needs of the plants/ soil, the market, labour availability, pest disease issues and other considerations.

Box 2: Examples of protected cropping rotations

Annual cropping plan for a polytunnel

Block	April	July	October	January
1	Cl French beans	Cucumbers	Salad packs	Early carrots
2	Tomatoes		Crimson clover	
3	Peppers		Over-wintered salad onions	
4	Cl French beans	Cucumbers	Salad packs	Early carrots

3 year cropping plan for a polytunnel

Year	Season	Crop
1	Summer	Tomatoes/peppers
1	Winter	Winter leaves*
2	Summer	Cucumbers/courgettes
2	Winter	Green manure*
3	Summer	Leaf and root crops
3	Winter	Alliums/legumes*

* could do two years leaves - brassica and non-brassica

Source: Roger Hitchings, Organic Research Centre Elm Farm

10.5 Pest disease and weed management

Pest disease and weed pressure is often higher in protected systems than in the field; warm, humid conditions favour insects and pathogens as well as crops! We have already identified good ventilation and the use of trickle/ drip feed irrigation systems as measures you can take to reduce pressure from foliar diseases, and the use of resistant varieties is a particularly important strategy in protected cropping.

As far as insect pests are concerned, biological control systems (see Section 3) can be very effective. There are now commercial formulations of many biological control agents for a wide range of pests and these are summarised in Table 6 below.

Table 6: Commercially available biological control agents

Pest	Biological control agent
Aphids	Lacewing and ladybird beetle larvae, parasitic wasps
Caterpillars	Parasitic wasps, *Bacillus thuringiensis* (Bt) Toxin
Mites	Predatory mites
Slugs	Nematodes
Whitefly	Parasitic wasps

Certain plants, notably phaecelia, marigolds and some herbs can attract predators already present in the fields into the tunnel and some combinations of crops, for example growing basil under tomato plants, also help to reduce pest problems. Furthermore, some polytunnel skins help to reduce certain pest and disease problems by modifying the light spectrum they let through

The less stringent rotation standards can lead to a build up of pests and pathogens in the soil, and these can be harder to deal with in a protected cropping context. Some growers have had success using biologically active composts such as those produced from Controlled Microbial Composting systems. Steam sterilisation is permitted as a last resort, but it is an extreme measure and kills the beneficial organisms as well as the pathogens

Mulches (plastic, biodegradable mulches or plant material such as straw) can be used to control weeds (in combination with trickle fed or drip irrigation to water the crop), although this also provides an ideal environment for slugs. Use of stale seedbeds, promoting vigorous crop growth to out-compete weeds and under-sowing with legumes can also help to reduce problems. However a certain amount of hand weeding is inevitable.

11. Top and soft fruit

11.1 Top Fruit

Orchards represent a significant commitment so careful planning is needed to ensure success. Many factors need to be taken into consideration and you should make sure your planting and cropping plan is agreed with your certifying body before going ahead

Top fruit takes two or more years to get established and existing orchards will take three years to convert to organic status.

Top fruit orchard. Credit David Frost

The site

Most orchards are below 150m above sea level. Shelter is very important, and if your proposed site is exposed you need to plant shelter belts at the same time as the fruit trees. Avoid the bottom of slopes where cold air drains down, creating frost pockets. This particularly important for pears, which flower earlier than apples.

The soil

The soil should be at least 450 mm deep, well drained and with a texture no heavier than a clay loam. You can improve drainage by installing a pipe drainage system with stone to the surface, but this needs to done at an early stage of the orchard's development.

Soil analysis is essential. Take soil samples from 0-150 mm and from150-300mm and test for pH, P, K and magnesium. If the pH is under 5.5 then you need to apply lime and subsoil after application to incorporate it to the right depth.

Top fruit is not a demanding crop in terms of nutrition, indeed high levels of N and K will reduce keeping ability after harvest.

Varieties

Different varieties have been developed for different markets including fresh markets, multiples, direct retail, and processing (including juice and cider), but you should note that some of the mainstream apple varieties do not suit organic production. These include Cox's Orange Pippin, Golden Delicious, Fiesta, Spartan and new introductions like Braeburn. The main pear variety is Conference, with Concord being a relatively recent addition. Resistant varieties, such as Discovery, Red Devil, and Red Falstaff, are very important for management of diseases such as scab, powdery mildew and canker, particularly because copper sprays are restricted under the organic standards.

Most apple varieties consist of a scion which is grafted onto a rootstock, both of which confer characteristics on the resulting tree. For example, a Bramley which is a vigorous triploid will still produce a big tree on a dwarfing rootstock, whilst a weak variety will produce a very small tree on a bigger rootstock such as MM106. Choosing the most appropriate rootstock for your site is a key decision. Dwarfing rootstocks are more common because they produce fruit earlier and stronger rootstocks are required on more marginal sites. M26 offers a good compromise between dwarfing and vigour Pears are usually grafted onto Quince C rootstock, which is semi dwarfing.

You should source organically raised trees where possible and where these cannot be obtained you need to talk to your certifying body about getting a derogation to use non organic stock.

Planting

This takes place from November to March in dry conditions. In small orchards planting can be done by hand, usually in teams of two, but on a bigger scale operations, post augers or mini diggers are used. Don't plant to deep, or you run the risk of the scion taking root losing control of the tree. All trees will need a good stake and a rabbit guard from planting.

The spacing depends on the type of tree you are using. 'Centre leader' trees have a straight vertical trunk with cropping branches low down usually on dwarf rootstocks. These trees use 3m x 3m spacings, whereas the standard varieties tend to go in at 5m x 3m. Where maiden trees are planted you can shape the tree by pruning. Three row and other ultra-intensive systems are not generally suitable for organic production as the trees tend to be more susceptible to disease.

The trees themselves are usually mulched with wood chip or bark or other organic material, which conserves soil moisture, helping to maintain yield and quality in dry spells. The areas in between the trees are often down to grass. Orchard mixes of grass are available which are dwarf, but do need some mowing or grazing.

Very few varieties are self pollinating, so you need insect pollinators – an arrangement with a local beekeeper will be useful in this regard. You need at least 3 full hives per hectare though April and May. Ideally, a quarter of the trees should be in blossom at any one time to get good pollination, and a mix of different varieties is usually grown to achieve this.

Pest, Disease and Weed Control

Regular crop monitoring is vital to identifying and managing diseases like scab, powdery mildew and canker, whilst aphids, mites and caterpillars will attack fruit and leaves. Biological control is especially important in orchard situations because natural predator and parasite populations can build up over several seasons. Some problems may emerge that will require permitted treatments, but you will need to think about their impact on the existing pest-predator balance before you use them.

Harvesting

Apples and pears going into storage have to be picked slightly under ripe and put in a cold store. Usually they are kept at 2°C or so and depending on the variety will keep until January. Harvest in dry weather, remove any blemished fruit at the time and keep checking the bins in store for sporadic rots.

11.2 Soft Fruit

Soft fruit crops such as strawberries, raspberries blueberries, currants, and gooseberries are attractive to organic growers, as the crops are high value and much in demand. Most crops are in the ground for 10 years or more except strawberries which are a 2 to 4 season crop.

Soils

In general soft fruit does best on well prepared, fertile soil with relatively high K and low N levels. Some crops have specific requirements. Blueberries, for example, need a pH below 6.0.

Varieties

The varieties you chose need to be suitable for your specific site and system. As with top fruit, the use of resistant varieties is important for disease management. However, this is a notoriously complex area and you would do well to seek guidance from a specialist advisor. Plants should be bought from organic propagators where possible. Where organic plants are not available, you need to talk to your certifying body about getting a derogation to use non organic stock.

Planting

Soft fruit is often planted through a polythene or polypropylene (mypex) mulch on raised beds, which improves topsoil depth and drainage. Table 7 describes planting systems for some of the main soft fruit crops.

Table 7: Planting systems for some soft fruit crops

Crop	Planting system
Strawberries	25,000 per Ha usually two rows on top of a 1m bed with 250 – 350 mm down row depending on variety vigour. In non mulched systems, the rows are 0.9m apart and plant 450 mm down row and allow runners to root in to form a solid matted row.
Raspberries	3.5 m x 450mm down row.
Bush fruit and blueberries	3.5 x 1.2 m, although blueberries could go in at a higher slightly higher density.

Pest disease and weed management

Pests include aphids, vine weevil, blossom weevil, caterpillar and capsid. As with top fruit, close monitoring of the crop is vital to decide on a control strategy either using permitted treatments or bought in biological controls. The main disease problems are fruit rots like botrytis and powdery mildew and these will be much worse in wet weather.

Harvesting

Strawberries, raspberries and blueberries are usually harvested over a period of about a month, picking approximately every 2 days. Gooseberries and red and black currants can be once-over harvested and will stand on the bushes for a week or two. Much of the harvesting is still done by hand, so the labour demand during this period is very high. Make sure you have arrangements in place as early as possible – there is nothing worse than watching the crop rot because there aren't enough hands on deck to pick it.

Once picked, you need to get the fruit into a chiller as soon as possible and keep at 2°C. This will give a shelf life of 2-3 days for strawberries and raspberries and 7-14 days for blueberries and bush fruit.

12. Further reading and references

General

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Hall, J; Tollhurst, I (2007). *Growing Green: Animal-Free Organic Techniques*. Vegan Organic Network (Key reference for soil fertility, field crops and protected crops).

Pest disease and weed control

Centre for Organic Seed Information (COSI) website (including access to the OrganicxSeeds database): www.cosi.org.uk

Garden Organic. *Organic weed management website*, http://www.gardenorganic.org.uk/organicweeds/index.php

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Soil Food Website: http://www.soilfoodweb.com/

Crop varieties

Centre for Organic Seed Information (COSI), website: www.cosi.org.uk

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Lind, K; Lafer, G; Scholoffer, K; Innerhofer, G; Meister, H (2003). *Organic Fruit Growing*. CABI Publishing.

13. Useful contacts

Information and advice providers

ADAS. ADAS Pwllperian, Cwmystwyth, Aberystwyth, Ceredigion SY23 4AB.
Tel: 01974 282229
Email: david.frost@aber.ac.uk
http://www.adas.co.uk
Contact: David Frost
Environmental consultancy, rural development services and policy advice. Partner in Organic Centre Wales.

Centre for Alternative Land Use (CALU), Henfaes Research Centre, Bangor University, Abergwyngregyn, LL33 0LB.
Tel: 01248 680450
Email: calu@bangor.ac.uk
http://www.calu.bangor.ac.uk
Contact: Kerrin Buckler
Knowledge transfer for horticulture, bio-energy, alternative crops, alternative livestock and/or farm woodlands. Farming Connect Development Centre.

Farming Connect
Tel: 08456 000813
http://www.wales.gov.uk/farmingconnect
Business management mentoring, training opportunities, technical and diversification advice. Knowledge transfer through sector development programmes. Supported by the European Agricultural Fund for Rural Development and delivered by the Welsh Assembly Government.

Garden Organic Ryton Organic Gardens, Coventry CV8 3LG.
Tel: 024 7630 3517
Fax: 024 7663 9229
Email: enquiry@hdra.org.uk
http://www.hdra.org.uk
Contact: Phil Sumption
Research and promotion of organic growing, farming and food.

Horticulture Network Wales. Aberglasney Gardens. The Folly. Llangathen, Carmarthenshire SA32 8QH.
Tel: 01558 668023
Fax: 01558 668998
http://www.horticulturenetworkwales.co.uk
Contact: Kevin Thomas
Business support project for horticultural businesses in Wales. Funded by EU Intereg IV.

Organic Centre Wales, Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Ceredigion SY23 3AL.
Tel: 01970 622248
Fax: 01970 622238
Email: organic@aber.ac.uk
http://www.organic.aber.ac.uk
Contact: Tony Little
Focal point for the dissemination of information on all aspects of organic food and farming. Manages Farming Connect Organic Development programme and the Organic Conversion Information Service in Wales.

Organic Conversion Information Service (OCIS).
Tel: 01970 622100
Email: organic-helpine@aber.ac.uk
http://www.organic.aber.ac.uk/farmers
Contacts: Tony Little, Philip Jones
Free service funded by the Welsh Assembly Government providing farmers and growers with information on the implications of organic conversion.

Organic Research Centre, Elm Farm Hamstead Marshall, Newbury, Berks, RG20 0HR.
Tel: 01488 658279
Fax: 01488 658503
Contact: Roger Hitchings
Research, development, knowledge transfer and advice on all aspects of organic food and farming. Partner in Organic Centre Wales.

Soil Association, Food and Farming Department, Bristol House, 40-56 Victoria Street, Bristol BS1 6BY.
Tel: 0117 914 2400. Fax: 0117 925 2504
Email: ps@soilassociation.org
http://www.soilassociation.org
Contact: Ben Raskin
Support and advice to farmers and growers on all aspects of organic food and farming.

Welsh College of Horticulture, Northop, Mold, Flintshire CH7 6AA.
Tel: 01352 841000
Fax: 01352 841031
Email: enquiries@wcoh.ac.uk
http://www.wcoh.ac.uk
Horticultural training courses and facilities.

Machinery rings

Machinery Ring Association of England and Wales
http://www.machineryrings.org.uk

Cadwyn Cymru / Link Wales (Mid & North Wales) Unit K, Henfaes Lane, Welshpool, Powys SY21 7BE.
Tel: 0800 783 1489
Email: gill@walesmr.com
http://www.walesmr.com
Contact: Gill Wood

South and West Wales Machinery Ring
Tel: 01437 720730
Email: gperkins@wwmr.co.uk
http://www.wwmr.co.uk
Contact: Graham Perkins, Managing Director

Organic Certification bodies

These are private companies, licensed by the UK government to implement the organic standards at farm level. In order to sell produce as organic, you must be registered with one of these bodies:

Biodynamic Agricultural Association, Demeter Scheme Coordinator, 17 Inverleith Place, Edinburgh, EH3 5QF.
Tel: 0131 624 3921
Fax: 0131 476 2996
Email: fionajmackie@hotmail.com
http://www.anth.org.uk/biodynamic

Organic Farmers and Growers Ltd, The Elim Centre, Lancaster Road, Shrewsbury, Shropshire SY1 3LE.
Tel: 01743 440512
Fax: 01743 461441
Email: info@organicfarmers.uk.com
http://www.organicfarmers.uk.com

Organic Food Federation 31 Turbine Way, Eco Tech Business Park, Swaffham, Norfolk PE37 7XD.
Tel: 01760 720444
Fax: 01760 720790
Email: info@orgfoodfed.com
http://www.orgfoodfed.com

Quality Welsh Food Certification Ltd., Gorseland, North Road, Aberystwyth, Ceredigion, SY23 2WB.
Tel: 01970 636688
Fax: 01970 624049
Email: qwfc@wfsagri.net

Soil Association Certification Ltd PO Box 805 Cardiff CF11 1FD.
Tel: 0845 1212321
Email: wales.cert@soilassociation.org
http://www.soilassociation.org

Welsh Assembly Government

Food and Marketing Development division (FMDD)
Market development support, including advice and capital grants.
Contact: Caryl Jenkins, Organic Sector Manager
Email: caryl.jenkins@cymru.gsi.gov.uk
Tel: 01970 613216

Welsh Assembly Government Divisional Offices
Administration centres. Queries relating to Organic Farming Scheme agreements should be addressed to your local office:

- *Caernarfon* (covering Gwynedd and Clwyd), Government Buildings, Penrallt, Caernarfon, Gwynedd LL55 1EP.
  Tel: 01286 674144
  Fax: 01286 677749
  Email: agriculture.caernarfon@wales.gsi.gov.uk
- *Llandrindod Wells* (covering Powys, Gwent, Mid, South and West Glamorgan), Government Buildings, Spa Road East, Llandrindod Wells, Powys LD1 5HA.
  Tel: 01597 823777
  Fax: 01597 828304
  Email: agriculture.llandrindod@wales.gsi.gov.uk
- *Carmarthen* (covering Carmarthenshire, Ceredigion and Pembrokeshire), Government Buildings, Picton Terrace, Carmarthen SA31 3BT.
  Tel: 01267 225300
  Fax: 01267 235964
  Email: agriculture.carmarthen@wales.gsi.gov.uk